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A MULTICHANNEL TIME DELAY ANALYZER

ARTHUR JOHN GROSS

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A MULTICHANNEL TIME DELAY ANALYZER

by

ARTHUR JOHN GROSS

A thesis submitted to the Graduate Faculty
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Master of Science

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ABSTRACT

GROSS, ARTHUR JOHN. A Multichannel Time Delay Analyzer. (Under the direction of DR. ARTHUR W. WALTNER).

A 26-channel time delay analyzer is discussed in terms of both the instrument design and the electrical performance. The pulses whose time distribution is to be measured are fed to an input circuit which standardizes the pulses in shape and amplitude, and repositions them in a standard time relationship with respect to the channel boundaries; the standardized pulses are fed to sequentially actuated gating circuits which channel them to one of 26 Dekatron scalers. The gating circuits are controlled by the output pulses from three cascaded magnetron beam switching tubes which are driven by a pulsed LC oscillator. The pulsed oscillator also provides the timing reference which controls the repositioning function of the input circuit.

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INTRODUCTION

Many nuclear experiments require an accurate means of measurement of the time distribution of electrical pulses resulting from some process; the time span of interest to the nuclear physicist may range from years to millimicroseconds. Various instruments have been designed to perform this function over time intervals too short to be measured manually. It is the purpose of this paper to describe one such instrument which operates in the microsecond range.

In a typical experiment for which a time delay analyzer is required, the experimenter desires to determine the time distribution of pulses with respect to some reference event, as for instance the length of time required for a metastable state to decay, measured with respect to its time of formation. Another example would be the measurement of the time distribution of nuclear events following a burst of particles from an electrostatic accelerator or a neutron chopper.

It would be desirable to be able to accurately measure the time required for each individual nuclear event to occur; however, in practice, it is only feasible to determine whether an event occurred in the finite time interval Δt; that is, between t and $t + \Delta t$. The particular experiment will dictate the width of the time interval used, since it must be narrow enough to define the structure of the time distribution, and at the same time wide enough to allow the entire time distribution of interest to be analyzed with a reasonable number of channels.

The problem of time analysis thus resolves itself as follows: the position in time, t, of a known finite time interval Δt, must be accurately specified with respect to some reference event occurring at time t_o. Further, the instrument must be capable of recording events which occur during the time Δt in a channel corresponding to this time interval, while rejecting events occurring outside of Δt.

The function of defining the time interval Δt is performed by a gate generator which produces a rectangular pulse of duration Δt when triggered. This gate generator might take the form of a one-shot multivibrator, a ring circuit, or, as in the case of the instrument described herein, a magnetron beam switching tube. The function of recording the events during the specified interval can be performed by a conventional scaler fed from a gating circuit which allows pulses to be registered only when they occur coincidentally with the rectangular pulse from the gate generator. The function of specifying the location in time of the selected interval requires the use of some timing device such as the pulsed LC oscillator described herein. The gate generator can be caused to trigger after a selected integral number of cycles of oscillation, thereby establishing the position in time of the interval Δt.

A multichannel analyzer consists of several gate generators with their associated gating circuits and scalers, each specifying a different location in time for its counting interval Δt. In obtaining the complete structure of the

time distribution, it is desirable to have contiguous time intervals; therefore the gate generators should be so arranged that immediately upon the closing of one gate, the next gate in sequence should open. This suggests the use of an inherently contiguous gate generator, such as the ring circuit or its equivalent, which will insure that one, and only one, gate is open at all times during the cycle of operation. Of course, a primary criterion in the design of the gate generators must be reliability, since as the number of channels is increased, the susceptibility to failures attendant upon greater complexity and larger number of components will also increase.

In addition to the factor of machine reliability, other points to be considered in the design of a multichannel time delay analyzer include:

1. Minimum channel width. For a given design, this will be limited by the maximum speed of operation of the gate generators and the resolving capability of the gating circuits.

2. Stability. This factor is perhaps most important, because the accuracy of the time distribution determination can be no better than the knowledge of the absolute calibration of the timing standard. A drift in the oscillator frequency used as a timing standard will introduce an error in the time scale of the distribution, while a change in relative channel widths due to transients in the timing standard will change the shape of the distribution.

3. Channel width uniformity. Equal channel widths would be desirable from a standpoint of convenience, but are

not absolutely necessary, as channel width can be taken into account in interpreting the data.

OBJECTIVES AND SCOPE

Tove (1957) describes a time analyzer utilizing a pulsed LC oscillator as a timing standard, with sequentially driven flip-flop circuits as gate generators. The machine had twenty channels. The simplicity and potential stability of the timing standard used in this machine made it a desirable research tool; however, the complexity of the gate generators required for even twenty channels was a serious drawback.

Von Dardel (1953) described an analyzer utilizing ring circuits taken in various combinations of coincidences as gate generators; here too, the complexity of the gate generators is the most serious drawback. This machine, however, utilized an input circuit which standardized the pulses in shape and repositioned them in time so as to eliminate resolution difficulties with the gating circuits and scalers.

In view of the reliability and stability objectives, it was decided that an analyzer be built utilizing a pulsed LC oscillator similar to that of Tove (1957) as a timing standard, and an input circuit similar to that of Von Dardel (1953). However, a more simple and reliable gate generator than either of these instruments was desired. On the basis of commercial literature published by the Electronic Tube Division of The Burroughs Corporation of Plainfield, New Jersey, it was decided to attempt to utilize magnetron beam switching tubes for this purpose. The initial design was intended primarily for use with the North Carolina State College Van de Graaff positive ion accelerator.

The scope included the design and construction of a pulsed LC oscillator chassis which includes the driving circuits for the beam switching tubes, an input circuit, a gate generator and gating circuit chassis, and power supplies for these circuits. A bank of forty cold-cathode Dekatron 4-decade counters and associated power supply, constructed by Palmer (1958), was available. These counters were modified by addition of an input discriminator to conform to the circuits utilized in the Atomic Instrument Company glow transfer counter model 162A. Such tests were to be performed as would permit the evaluation of the design, and a typical time analysis experiment performed to demonstrate the usefulness of the instrument. Specifically, Epling (1960) was to evaluate the time dependent behavior of thermal neutrons in light water utilizing the Van de Graaff accelerator as a pulsed neutron source.

DESIGN OF THE INSTRUMENT

A block diagram of the time delay analyzer is given in Figure 1. The reference pulse from the accelerator triggers a univibrator which gates the Hartley oscillator. The oscillator output is fed to a paraphase amplifier adjusted to deliver oppositely phased pulsed sinusoids to the beam switching tube driving circuits. These driving circuits are identical biased discriminators which deliver negative switching signals to the grids of the beam switching tubes, and in addition, supply positive timing markers to the input circuit for standardization of the pulses to be analyzed. Each of the twenty-six active beam switching tube targets controls a dual cathode follower gating circuit serving as the input to one of the Dekatron scalers. The pulses to be analyzed are shaped in a conventional Schmitt circuit, and injected at one plate of a bistable trigger, thus tripping it into its alternate stable state. The timing markers from the beam switching tube driving circuits are inverted, delayed in a two microsecond delay line, and fed to the input grid of the bistable trigger, causing it to return to its original stable state. The output of the bistable trigger is differentiated and the trailing edge is shaped and amplified to form the standardized input pulse for the gating circuits. The two microsecond delay in the timing of these standardized pulses insures that they will fall well within the open time of the gating circuits rather than occurring at or near the boundary, which could lead to ambiguity in the channel assignment of any

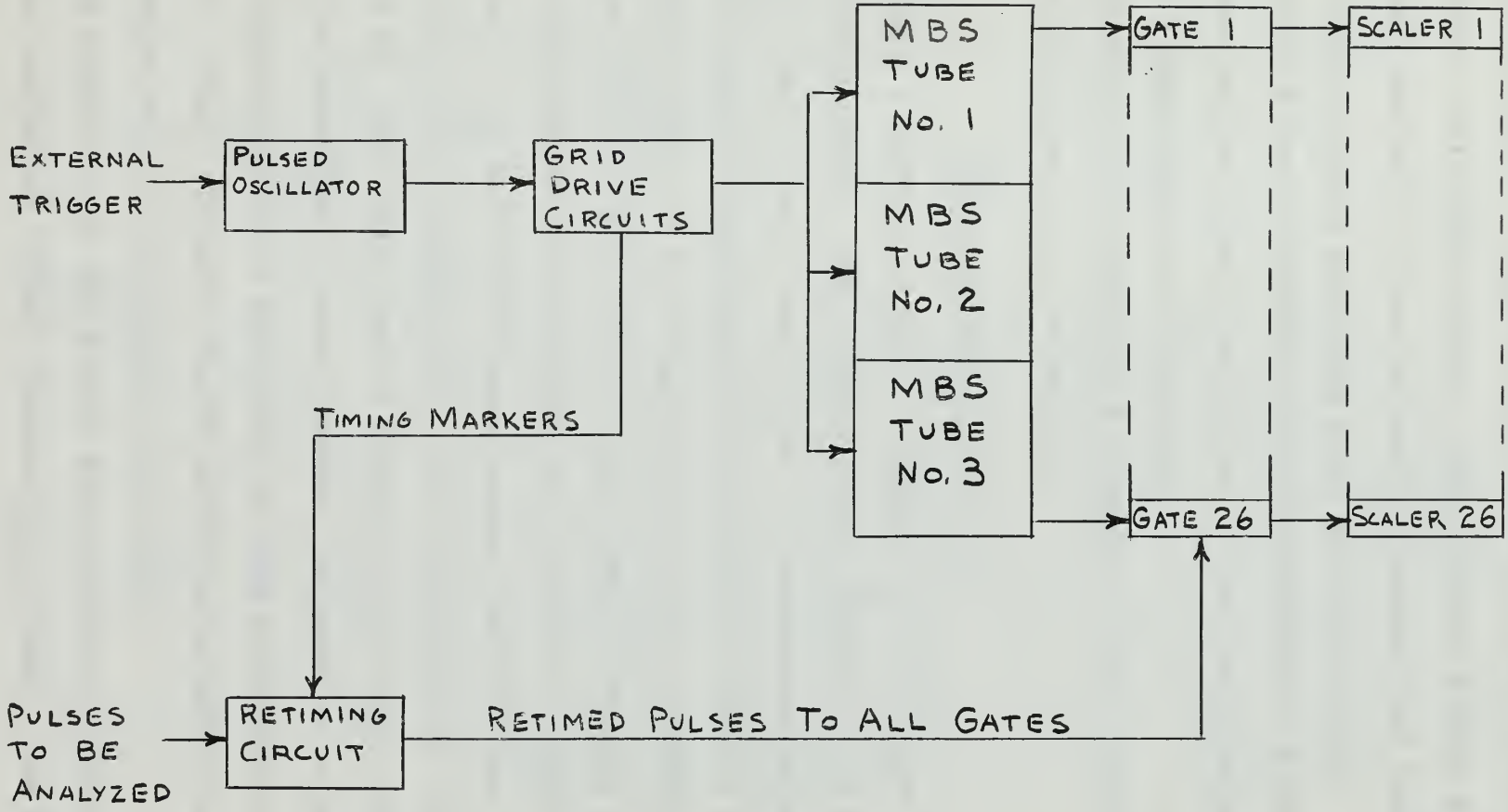
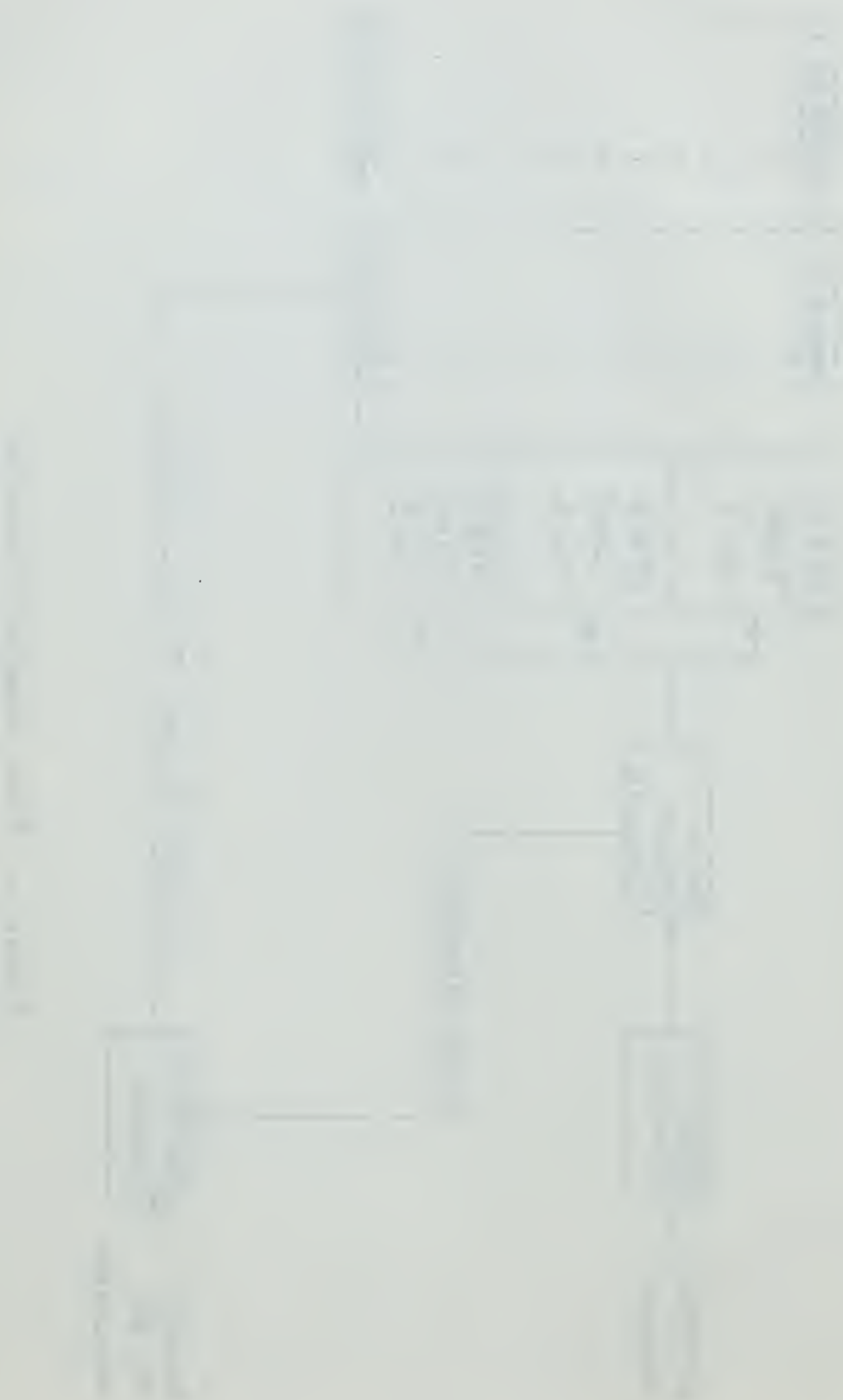


Figure 1. Block diagram of analyzer



individual pulse. This procedure eliminates the inaccuracy of the definition of channels due to sensitivity characteristics of the individual scalers. The channel widths will be determined entirely by the separation between the timing pulses from the beam switching tube driving circuits. The resolution of the instrument will be determined by the design parameters of the input circuit, which can be optimized to achieve a high degree of stability.

Referring now to Figures 2 through 13, the circuitry will be considered in more detail.

Pulsed Oscillator Circuit

Figure 2 shows a schematic diagram of the pulsed LC oscillator circuit. The trigger input consists of a positive pulse of about 25 volts amplitude. In measurements utilizing the Van de Graaff accelerator, this pulse is derived from the trailing edge of the beam current pulse; an Atomic Instrument Company model 204-C linear amplifier with short input time constant was found to be a suitable trigger amplifier. The positive trigger causes the left hand side of univibrator V1 to conduct for a time determined by the combination R1 - C1; this time is chosen to be longer than the sum of the twenty-six channel widths. A negative square wave of about 120 volts amplitude is thus delivered by V1. The dual cathode follower V3, V4 serves as a buffer in coupling this square wave to the pulsed oscillator.

The operation of the pulsed LC oscillator is as described by Elmore and Sands (1949), Chance et al (1949), and Millman

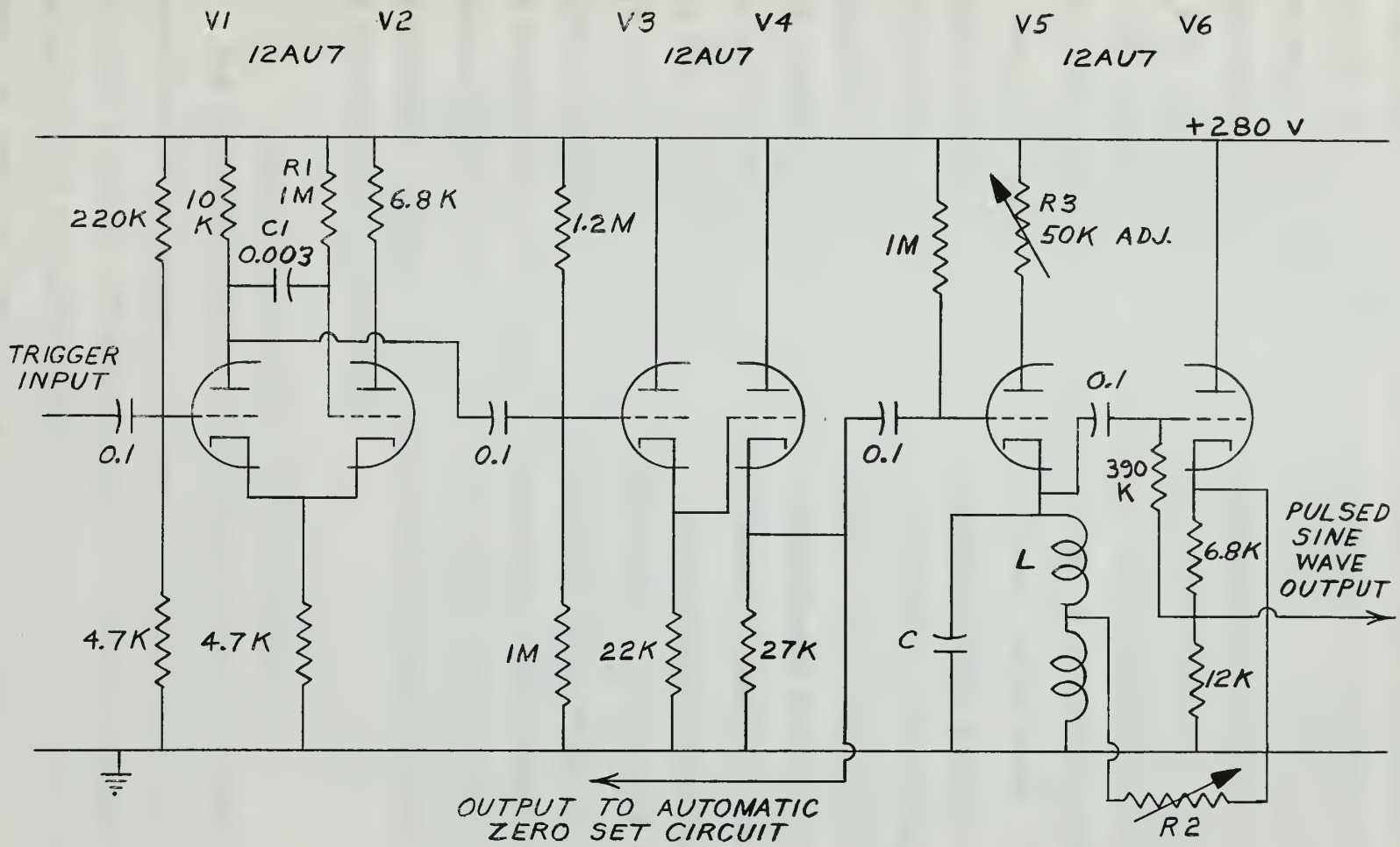


Figure 2. Pulsed oscillator circuit

and Taub (1956). The negative pulse applied to the grid of V5 cuts off the current flow in this tube, causing the parallel LC tank circuit to oscillate at its characteristic frequency $1/2\pi\sqrt{LC}$. The peak amplitude of the oscillations is given by $I\omega L$, where I is the quiescent current in V6, ω is 2π times the resonant frequency, and L is the inductance of the oscillator coil in henrys. The adjustable resistance R3 allows the quiescent current in V5, and thus the amplitude of the oscillations, to be varied over a wide range. The signal at the cathode of V5 is applied to the grid of the cathode follower V6, the output of which is fed through adjustable resistor R2 to the center tap of the inductance L. This positive feedback serves to compensate for the losses in the oscillator tank circuit and prevent a decay in the amplitude of the oscillations. R2 is experimentally adjusted to give oscillations of constant amplitude. At the end of the negative square wave, V5 again becomes conducting so that the oscillations are rapidly damped out. The output of cathode follower V6 is thus a sine wave train starting with the external trigger and ending with the trailing edge of the univibrator square wave.

Beam Switching Tube Driving Circuit

The beam switching tube driving circuit is shown schematically in Figure 3. Three distinct outputs are desired from this circuit: First, a train of positive pulses with separation 1/2 T, where T is the period of the oscillations; second, a train of negative pulses with separation T, phased

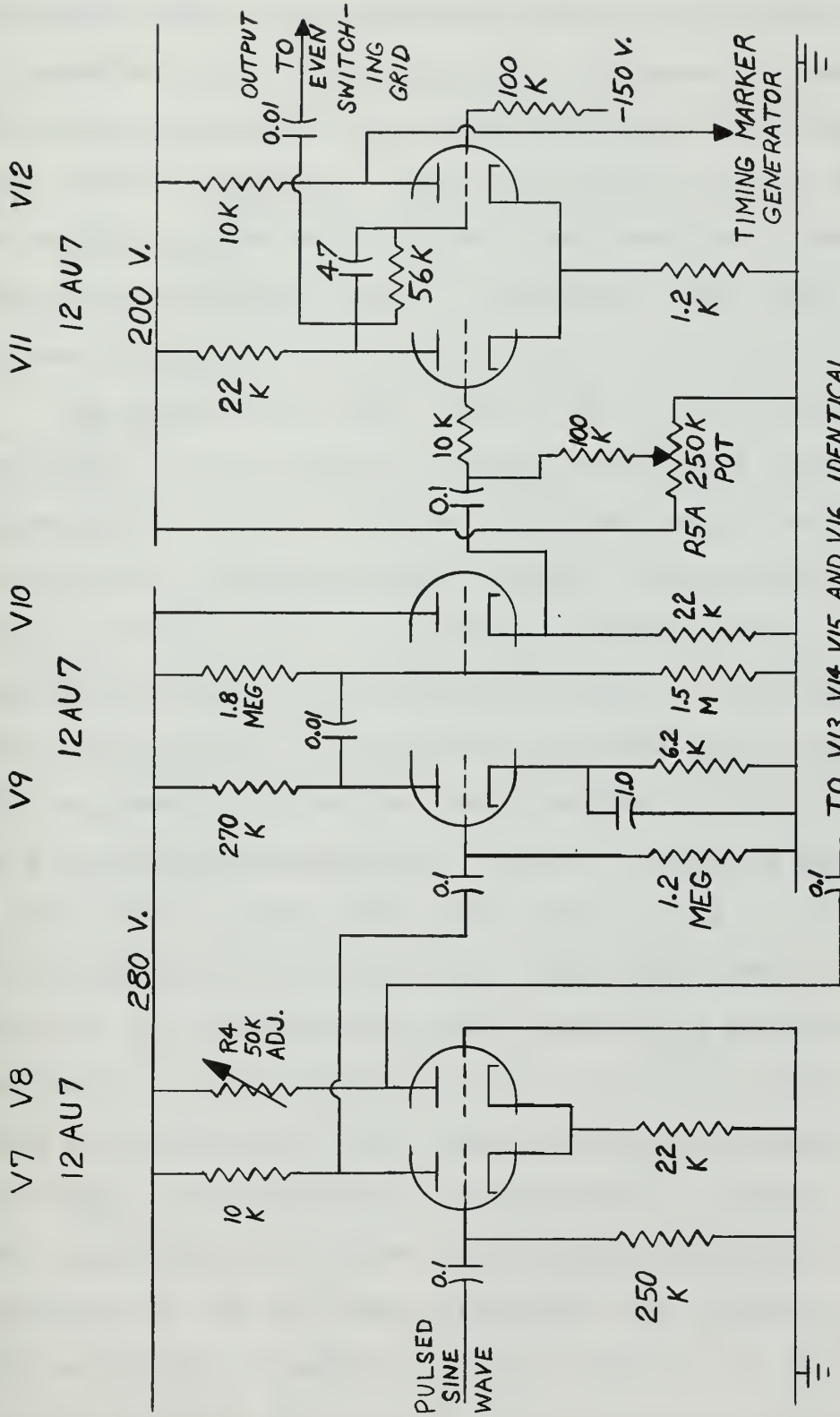


Figure 3. Beam switching tube driving circuit

to occur each time the pulsed sine wave crosses the zero amplitude axis in the negative direction; and third, a train of negative pulses with separation T, phased to occur each time the pulsed sine wave crosses the zero amplitude axis in the positive direction. The utilization of these two trains of negative pulses will become clear when the operation of the beam switching tubes is considered. The train of positive pulses is required for the operation of the input circuit.

The pulsed sine wave train is fed to the paraphase amplifier V7 and V8 which delivers oppositely phased sinusoidal outputs to the two identical amplifier and discriminator circuits which follow. The operation of one of these circuits will be considered: Triodes V9 and V10 amplify and invert the sinusoidal signal. This signal is fed to the input of the biased discriminator V11 and V12. V12 is normally conducting, and the bias on the grid of V11 is adjusted experimentally by means of resistor R5A to such a point that a small positive voltage at the input causes V11 to conduct and V12 to cut off. Thus, each time the sine wave input to the discriminator goes positive, a negative pulse is available at the plate of V11, and a positive pulse is available at the plate of V12. When the sine wave input goes negative, the discriminator returns to its original condition. The operation of the other amplifier-discriminator circuit is identical to the one just discussed, with opposite phase. The two trains of negative pulses required are thus available at the plates of V11 and V15. The outputs at the plates of

V12 and V16 are fed to the input circuit, where they are differentiated, the negative portions are clipped, and the resultant positive pulses are mixed to get the desired train of positive pulses of separation 1/2 T.

Beam Switching Tube Circuit

The beam switching tube circuit is shown schematically in Figure 4. First the operation of the beam switching tubes will be discussed, followed by a description of their function as gate generators. The mechanical arrangement of the beam switching tube is shown in Figure 5. The tube has cylindrical structure. A central cathode is surrounded by ten identical arrays of elements, numbered from zero to nine. A small permanent magnet is attached to the glass envelope to provide an axial magnetic field of about 450 gauss. Each array consists of three elements: a spade, a target, and a switching grid. The spade electrodes directly affect the configuration of the electric field between the cathode and the coaxial arrays of elements. The spades are connected to a positive supply voltage through individual series load resistors. The targets are likewise connected to a positive supply voltage through individual series load resistors. The cathode may be operated at ground potential, or preferably, at a small positive potential supplied by a resistor in series with the cathode. A small bypass capacitor across the cathode resistor serves to eliminate transients which would otherwise occur during the transition of the electron beam from one array to the next one. This cathode bias improves

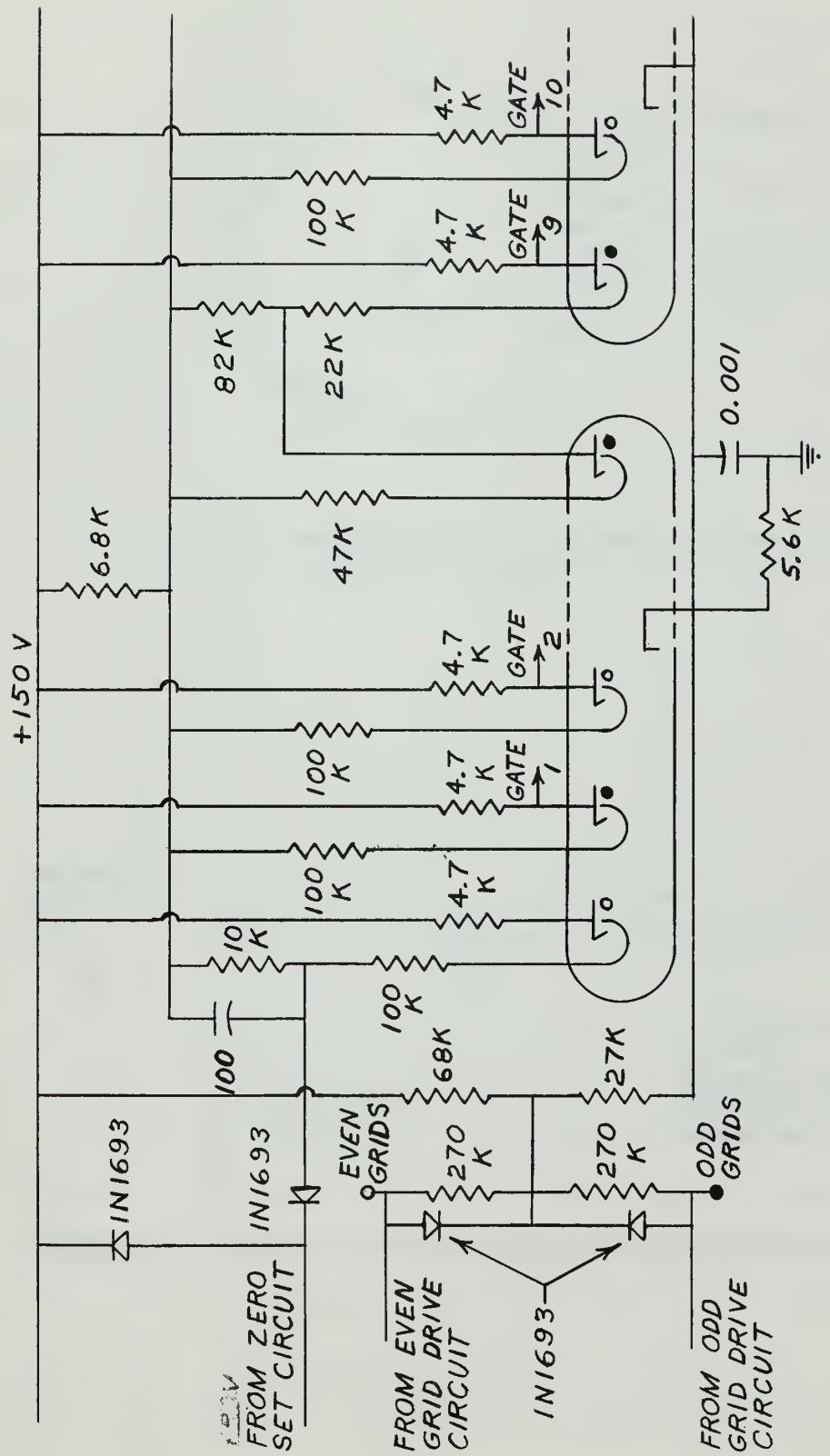


Figure 4. Beam switching tube circuit

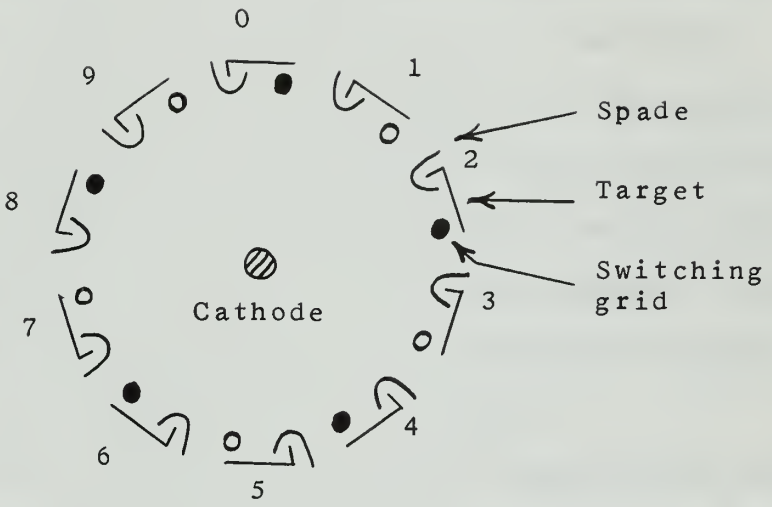


Figure 5. Mechanical arrangement of beam switching tubes

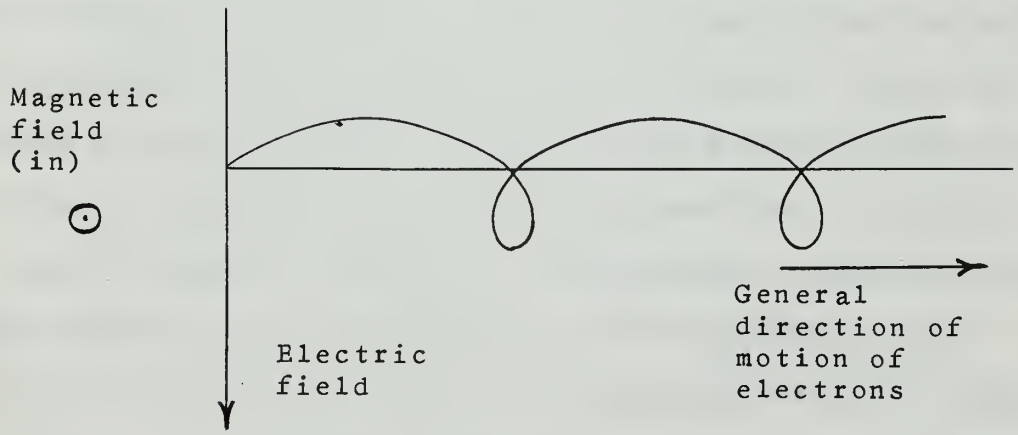


Figure 6. Motion of electron in crossed fields

stability by introducing degeneration, or negative feedback, thereby reducing the effect of supply voltage fluctuations or slight differences in characteristics of individual arrays. The switching grids are connected in two groups, the odd numbered grids in one group, and the zero and even numbered grids in the other. The switching grids are operated at a positive potential of 25 to 30 volts with respect to the cathode. This bias is obtained from a resistive bleeder between the supply voltage and the cathode.

The operation of the beam switching tube may be discussed in a qualitative manner by considering the nature of the motion of an electron in perpendicular electric and magnetic fields. (Millman and Seely, 1951; Milman and Taub, 1956) The path of an electron introduced with non zero initial velocity into such crossed fields is shown in Figure 6. The precise shape of the path will depend on the initial velocity of the electron when introduced into the fields. Since the electrons are emitted from a heated cathode with a spread of velocities, a family of such curves is possible. A path of this type is termed a trochoid. The important characteristic of these paths is that the motion of the electron in the direction of the electric field is oscillatory and of restricted amplitude. The general motion of the electron upon which the oscillatory motion is superimposed is in the direction perpendicular to the electric field, that is, in the direction of the electric equipotential surfaces. Because of the spread of velocities of the emitted electrons, individual

electrons will follow different trochoidal paths, but the electrons generally will form a broad beam which follows an equipotential.

The characteristics of an electrode placed in a region of perpendicular electric and magnetic fields may be appreciated by considering the simple configuration shown in Figure 7. Two parallel plates maintained at 0 and 100 volts, respectively, provide an electric field, while an external magnet provides a magnetic field perpendicular to the figure. A heated cathode maintained at 50 volts and situated midway between the plates emits electrons. These electrons will follow trochoidal paths along the 50 volt equipotential. If an electrode is situated midway between the plates, and maintained at 50 volts, the electron beam will follow path (1) to the electrode and will be collected. If the electrode is maintained at a potential lower than 50 volts, the 50 volt equipotential lies above the electrode and the electron beam will follow path (2). Similarly, if the electrode is maintained at a potential higher than 50 volts, the beam will follow path (3). A volt-ampere characteristic, or plot of electrode current versus electrode voltage will have a maximum at an electrode voltage of 50 volts, since at that voltage, the beam goes directly toward the electrode. As the electrode voltage is varied either direction from this 50 volt value, the electrode current will decrease as only part of the electron beam is collected. The characteristic will have the shape of the solid curve of Figure 8. If, as is shown in

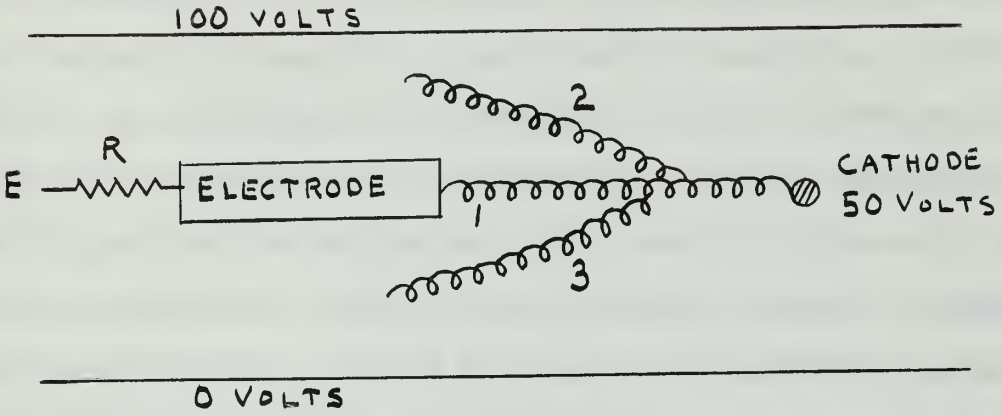


Figure 7. Effect of electrode on electron beam

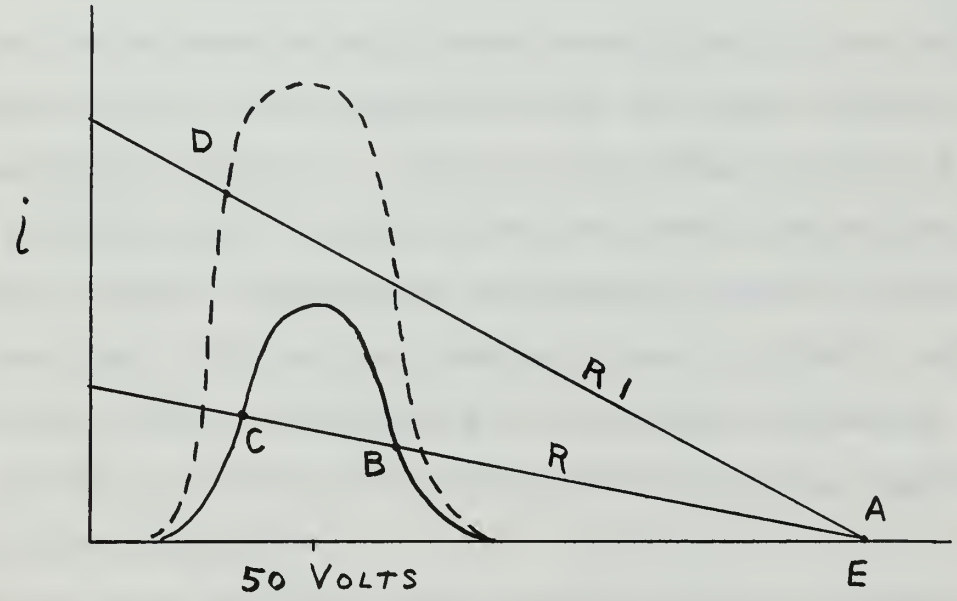


Figure 8. Volt-ampere characteristic of electrode

Figure 7, the electrode voltage is determined by the drop across a resistor R in series with the electrode and connected to a supply voltage E, the permissible operating points are given by the intersection of the load line corresponding to R with the volt-ampere characteristic. These permissible operating points are designated A, B, and C in Figure 8. At point A, no current flows to the electrode, and its voltage is maintained at E. Point B is seen to be unstable, as any change in current produces a change in the electrode voltage in such a direction as to cause a further change in current in the same direction as the original disturbance. Point C is seen to be a stable operating point, as any disturbance in electrode current changes the electrode voltage in such a direction as to restore equilibrium conditions. This point corresponds to the beam skimming along the upper surface of the electrode in Figure 7. The electron beam is not in a stable position when it skims along the lower side of the electrode, as this corresponds to operating point B. Thus it is seen that the electron beam will tend to flow in only one position, that corresponding to the stable operating point, and will be locked into this position by the characteristics of the electrode.

In the beam switching tube, supply voltage and magnetic field strength are so chosen that when power is first applied, no current flows, as the electron beam simply circles around the cathode as in a cut-off magnetron diode. This corresponds to operating point A in the simple configuration of Figure 7.

If the zero spade is momentarily lowered to near cathode potential, an equipotential surface will be established between the cathode and the zero spade, and electrons can follow trochoidal paths out to this spade. The spade series load resistors are chosen to be large enough (100K) that a current of one milliampere flowing to the spade will hold it at near cathode potential, permitting the electron beam to be locked in that position once formed. The beam skims along that side of the spade which corresponds to the stable operating point. This is the "clockwise" side of the spade as viewed in Figure 5. The remainder of the beam current, about six milliamperes, will flow to the target associated with the zero spade, causing a drop across the 4.7 K target series load resistor which can be coupled out as a useable signal. In order to cause the electron beam to move to the number one array, a negative pulse is applied to the zero switching grid. This diverts part of the electron beam to the number one spade, lowering its potential to near cathode potential. The stable operating point is now the clockwise side of the number one spade, thus the beam switches raddidly to the number one array. Since the grids are connected in two groups, even and odd, they can be driven by alternate negative pulses, causing the beam to advance one position for each negative pulse. The target output will therefore be a negative square wave of 28 volts amplitude with duration equal to the spacing between the negative grid driving pulses. These square waves are used to control the gating circuits.

Several beam switching tubes can be connected in cascade by paralleling the even and odd switching grid groups in all the tubes, and by providing a means whereby the last array in each tube turns off the beam current in that tube while turning on the beam current in the first position in the next tube. This feature of clearing the beam in one tube while turning on the beam in the next tube depends on a change in the volt-ampere characteristic encountered when two adjacent spades are both instantaneously at near ground potential, as will occur during switching of the electron beam from one array to the next. The broader electric field obtained by two spades being at near cathode potential during switching results in an increased peak in the volt-ampere characteristic of the clockwise spade, as shown by the dashed curve of Figure 8. If a spade load resistor R1, smaller than R, is chosen such that its load line intersects only this dashed curve, the electron beam will be switched to this array and will tend to lock in at point D. However, as soon as the potential of the counter-clockwise, or lagging, spade rises to the value of the supply voltage, as it will when there is no longer a drop across its spade load resistor, the electric field is narrowed to that which corresponds to only one spade at near cathode potential. In this situation, the volt-ampere characteristic of the clockwise spade reduces to the solid curve of Figure 8. Since the load line of R1 does not intersect this characteristic at all, there is no stable operating point corresponding to a beam current flowing to this array;

thus the beam will clear itself, or cease to flow, and the tube will again be in the cut off condition in which the electron beam simply circles around the cathode.

For the circuitry used, a 47K spade load resistor in the last array will cause the beam to clear itself, that is, to shut off, immediately after switching to that position. The short negative pulse generated at the target is used to lower the potential of the first spade in the next tube, thereby causing current to flow to that array. The last position in the group of cascaded tubes simply clears the beam current so that all tubes are in the cut off condition to await a new cycle of events.

Thus it is seen that as the beam steps from array to array, a negative square wave is produced at each target in turn. Each target controls one gating circuit and associated scaler. In this way the desired objective of channeling events as a function of time is achieved.

It is of interest to note that although three beam switching tubes comprising a total of thirty arrays are used, only twenty-six channels are available. The zero position is utilized to form the beam in a position of readiness for a new cycle of operation; and positions nine, nineteen, and twenty-nine are used to clear the beam in their respective tubes and initiate the beam in the next tube in sequence.

Automatic Zero Set Circuit

The automatic zero set circuit shown in Figure 9 consists of a delay univibrator, a cathode follower buffer, and a

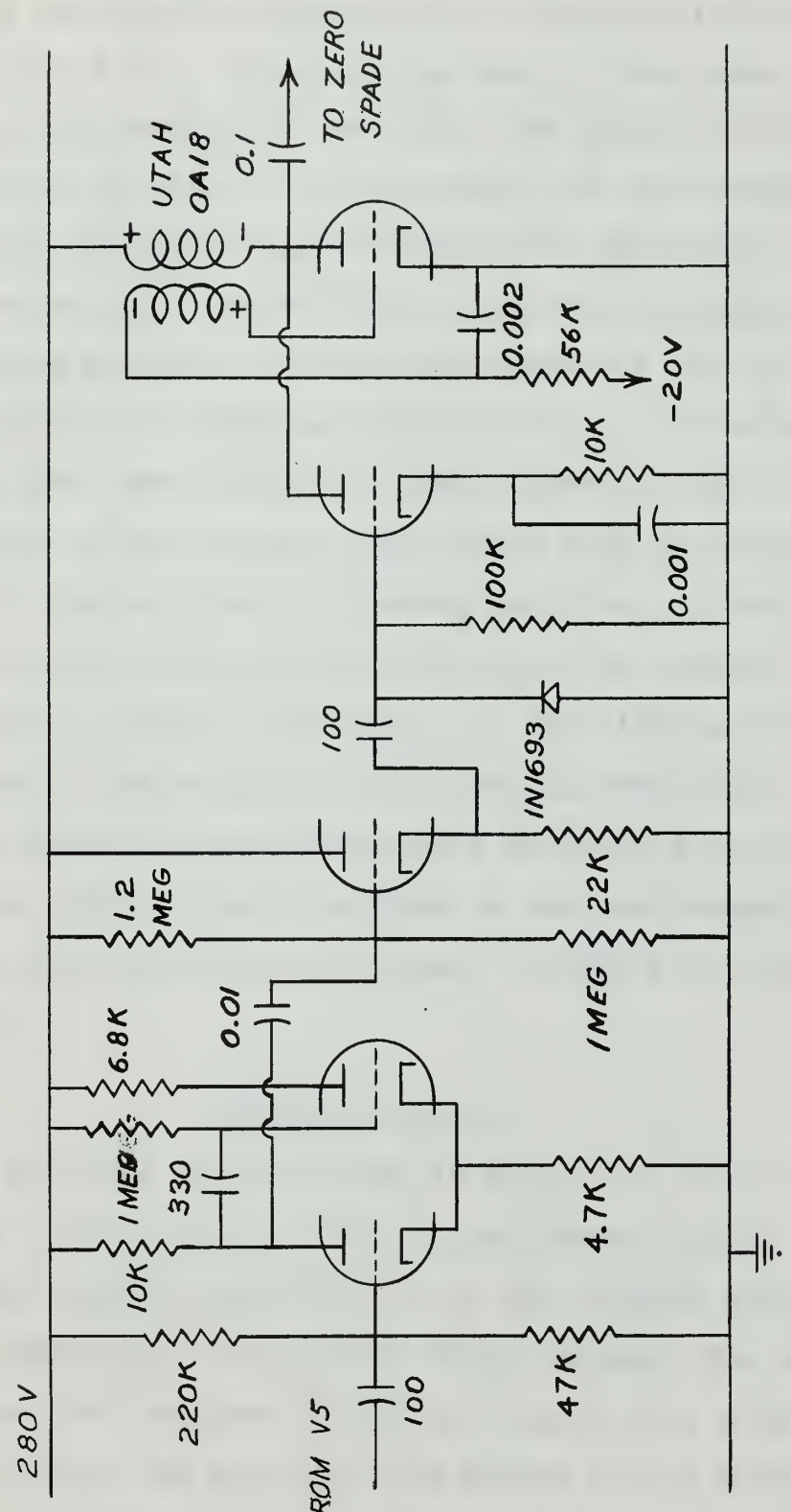


Figure 9. Automatic zero set circuit

triggered blocking oscillator. The univibrator pulse which initiates the pulsed oscillations is differentiated and fed to the grid of V17. The trailing edge of the pulse triggers the delay univibrator V17 and V18. The period of this delay is chosen to be about 70 microseconds, or long enough to insure that the pulsed oscillations have damped out completely, and therefore that the switching grid driving signals are no longer being produced. The delayed pulse is fed to the grid of the parallel triggering amplifier V20 by the cathode follower V19. The cathode follower serves to reduce the interaction of the blocking oscillator with the delay univibrator. The parallel triggering amplifier injects a negative pulse at the plate of V21 which is coupled to the grid as a positive pulse by the action of the blocking oscillator transformer. The output of the blocking oscillator is a negative pulse of four microseconds duration and 140 volts amplitude. This pulse is coupled to the zero spade and causes the beam to form at the zero array to await a new cycle of operation.

Retiming Circuit

The retiming circuit shown in Figure 10, similar to one described by Von Dardel (1953), substitutes a pulse, having a standard position with respect to the channel boundaries, for the arbitrarily distributed input pulses. The pulses to be analyzed are inverted in V22 and shaped in a standard Schmitt circuit V23 and V24. The output of the Schmitt circuit is differentiated and the negative portions are clipped by the

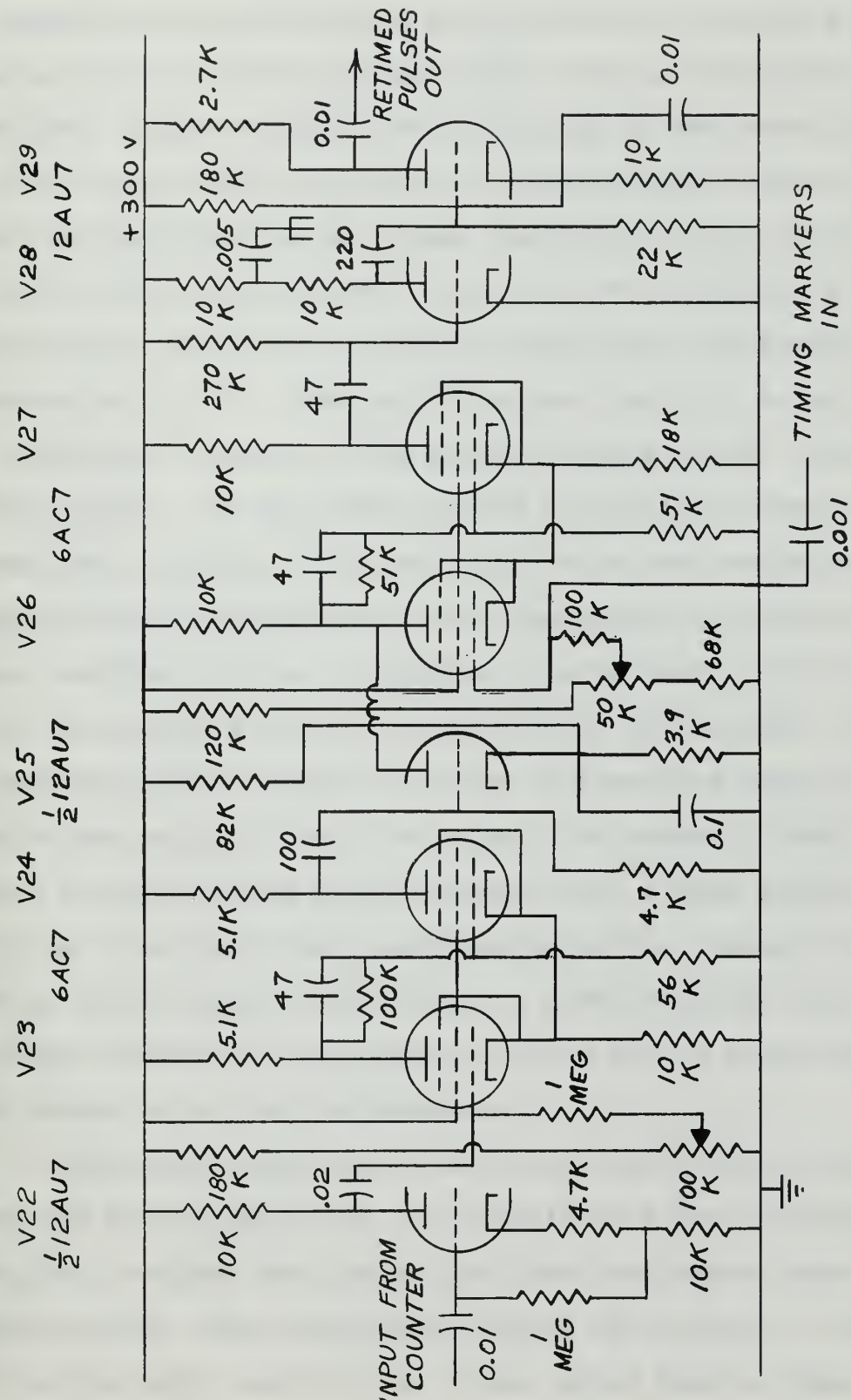


Figure 10. Retiming circuit

normally cut off amplifier V25. The resulting negative output pulses at the plate of V25 are injected at the plate of the normally non-conducting tube V26. V26 and V27 form a cathode coupled trigger circuit, with the bias of V26 being chosen so that the circuit operates in the bistable region. The delayed negative timing pulses derived from the switching grid driving circuits are fed to the grid of V26. An input pulse will cause V26 to conduct, and since the circuit is bistable, it will continue to conduct until it is cut off by a signal at the grid. The delayed timing pulses provide this signal. At the plate of V27 a positive square wave is obtained, starting with the input pulse, and ending with the next delayed timing pulse. This waveform is differentiated, the positive portion is clipped by grid conduction of V28, and the negative pulse is amplified by V28 and V29. The function of this circuit is thus to store the input pulse, which may occur at any time during the channel, until the next delayed timing pulse releases this stored information, giving it a fixed time relationship to the channel boundaries. If no input pulse occurs during a given channel, the bistable trigger remains in the state in which V27 is conducting, and no output pulse can be produced.

Since the input pulse may occur very close to the delayed timing pulse, it is possible that the bistable trigger may not complete the transition from one stable state to the other before the timing pulse resets the trigger. This situation will result in an output pulse smaller than normal.

Since it is desirable to have the output pulses standardized in amplitude in order that individual scaler input characteristics will not affect the likelihood of a given pulse being counted, it was decided that an amplitude selector should follow the input circuit. In this way, pulses smaller than some arbitrarily chosen cutoff value can be rejected prior to delivery to the gating circuits, and differences in the individual scaler inputs will play no part in determining effective channel width.

Figure 11 shows this gate driving circuit. The retimed pulses are inverted by V30 and fed to the grid of V31. V31 and V32 comprise a Schmitt trigger with the bias on the grid of V31 chosen experimentally to give stable operation as a pulse height selector. The output at the plate of V32 is differentiated, clipped, and amplified by V33, V34, and V35. The result is a standardized negative pulse of about 60 volts amplitude and 1.5 microseconds width at half-maximum.

In order to drive the low input impedance of the twenty-six paralleled gating circuits, a cathode follower with extremely low cathode resistor is utilized. V36 serves as a buffer to drive V37, consisting to both halves of a 6AS7 paralleled to act as a cathode follower. The bias on the grids of this cathode follower is chosen experimentally to give a cathode voltage of 70 volts developed across the 500 ohm resistor. This circuit can successfully deliver the standardized pulses to the gating circuits.

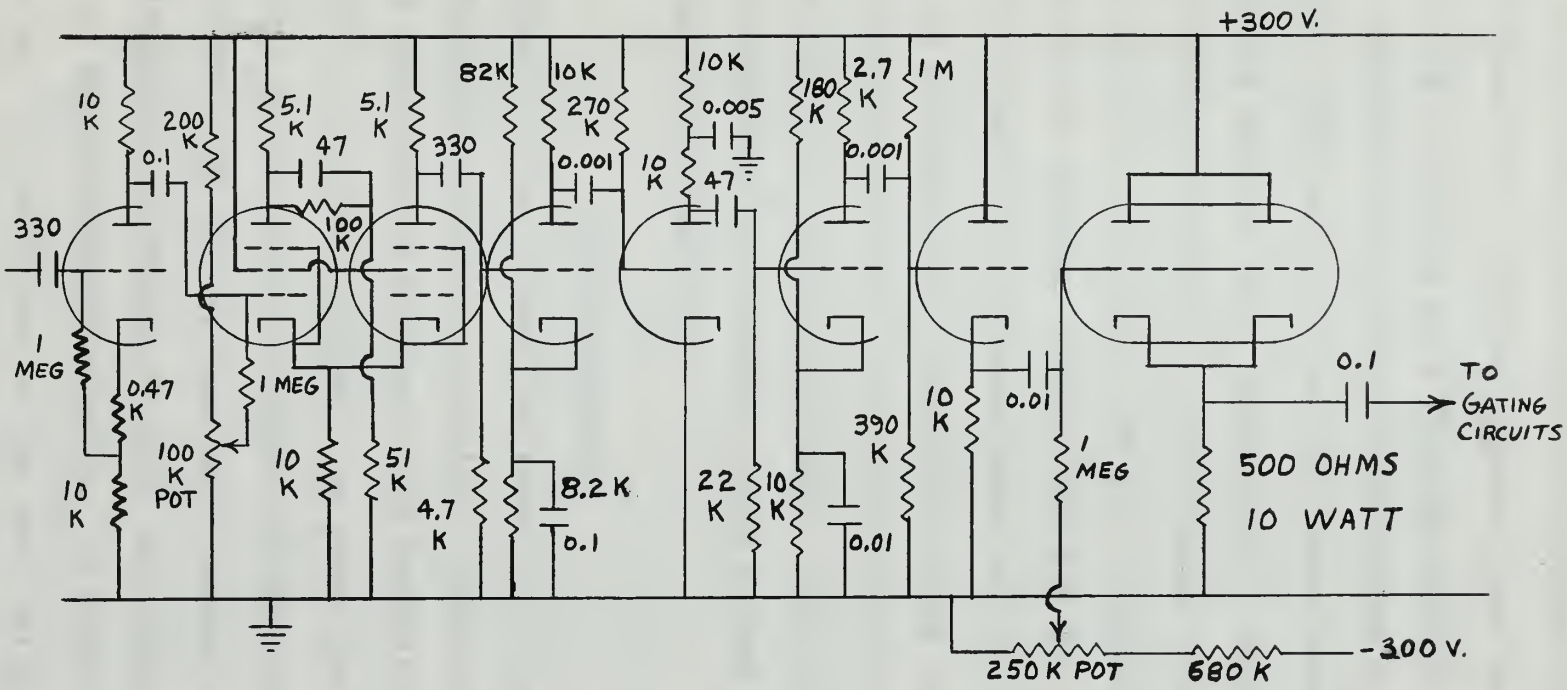


Figure 11. Gate driving circuit

Timing Marker Generator

The circuit which develops the delayed timing pulses is shown in Figure 12. Positive signals from the plates of V12 and V16 in the switching grid driving circuits are differentiated and applied to the grids of the normally cut off tubes V38 and V39. The output of each of these tubes is capacitively coupled to the grid of V40. This circuit serves to invert and mix the pulses coinciding with the channel boundaries. The output of this mixer is amplified and inverted by V40 and V41, and shaped by the Schmitt circuit V42 and V43. The output of the Schmitt circuit is differentiated and applied to the normally cut off amplifier V44, which clips the negative portion. The delay line in the plate circuit of V44 delays the output pulse by two microseconds. The cathode follower buffer V45 delivers the delayed timing pulses to the retiming circuit shown in Figure 10.

Gating Circuits

A typical gating circuit is shown in Figure 13. This is one of twenty-six identical circuits. These gating circuits are of the dual cathode follower type described by Chance *et al* (1949). With no signal applied, the grids are held at a positive bias of 80 volts, supplied through separate one megohm grid resistors. The two triodes will conduct a total of about nine milliamperes, or enough to hold the cathode at a positive potential of approximately 90 volts. If either one of the triodes is cut off by virtue of its grid being driven negative

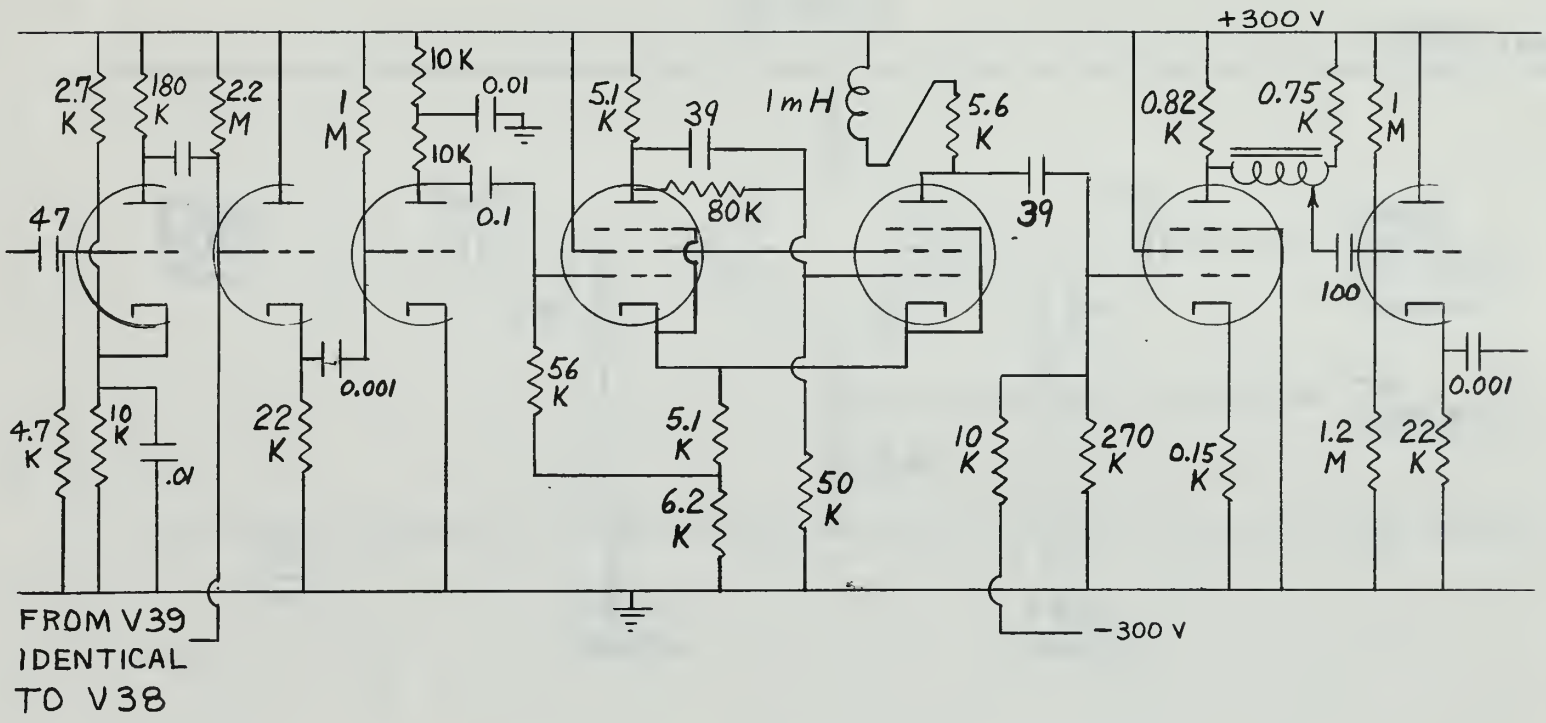


Figure 12. Delayed timing marker generator

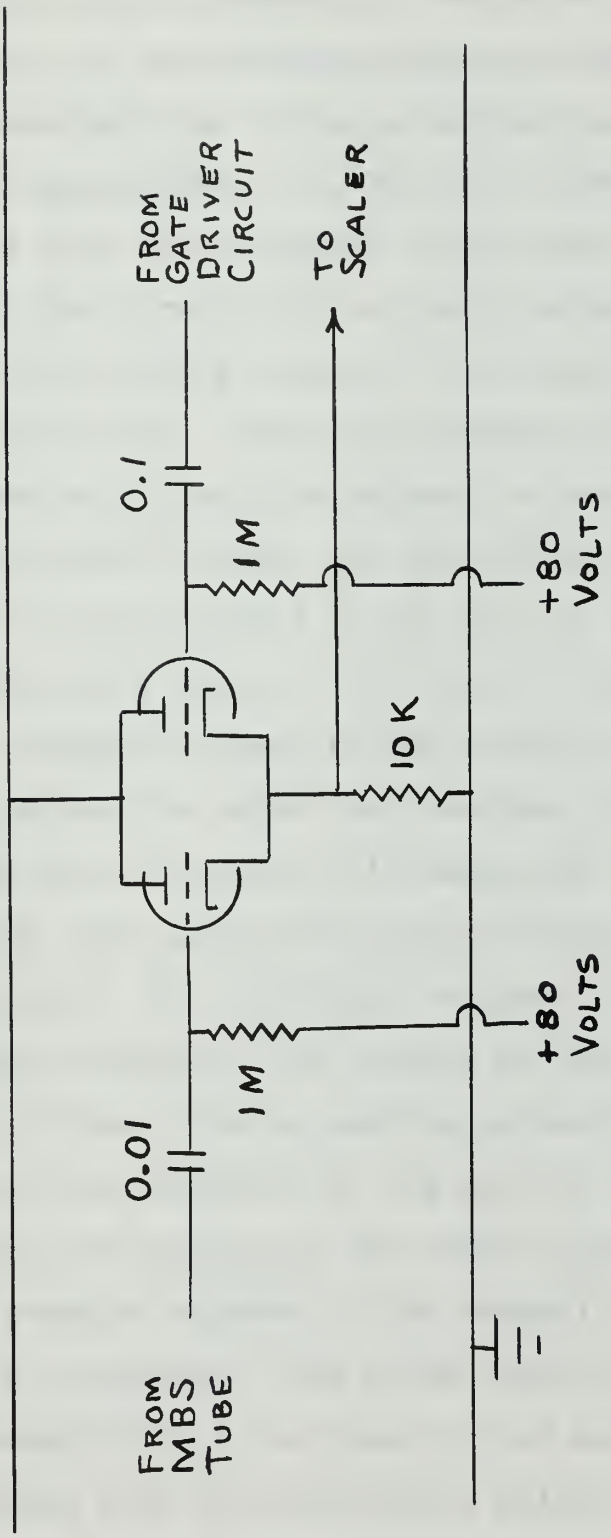


Figure 13. Typical gating circuit

the other triode will increase its conduction to maintain the output potential at the cathode relatively constant; only a very small "pedestal" due to the cutoff of only one triode will appear in the output. If, however, a negative signal appears at the grid of the second triode while the first is still cut off, the circuit will act as a cathode follower and will transmit the applied signal to the output terminal.

As utilized in the time delay analyzer, the output from one of the beam switching tube targets is connected to the grid of the left hand triode, and the pulses from the gate driving circuit are connected to the grid of the right hand triode. If the two signals do not occur in coincidence, only a very small pedestal appears in the output; if the two signals are in coincidence, the pulse from the gate driving circuit is transmitted at very nearly full amplitude to the scaler associated with this particular gating circuit.

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The scalers, which were constructed locally for general counting applications (Palmer, 1958), are identical in all

respects to the Atomic Instrument Company model 162A scaling strip, and as such, require no additional discussion.

Typical waveforms as found at various points in the circuit are sketched in Figure 14.

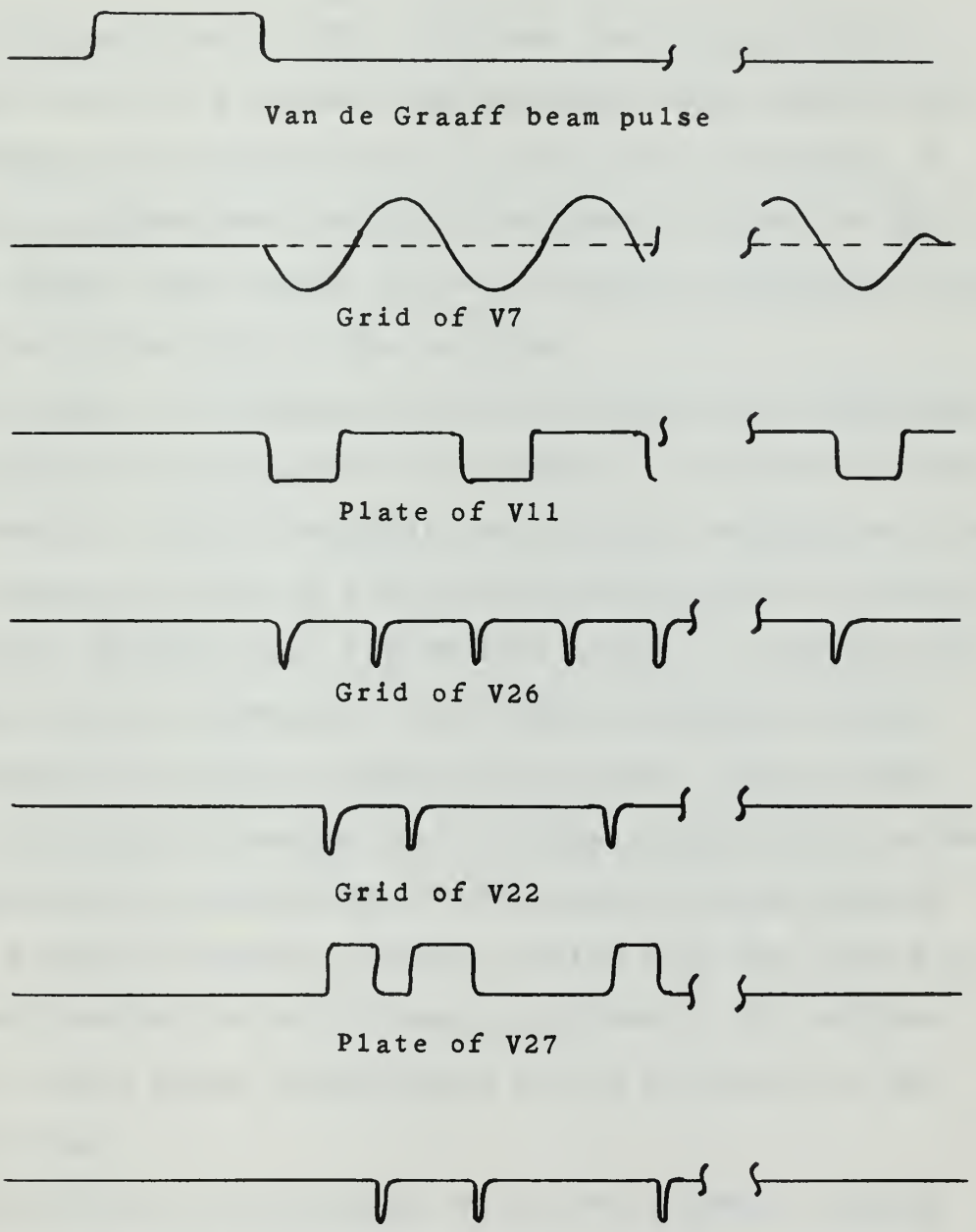

Figure 14. Waveforms

OPERATIONAL PERFORMANCE

A Tektronix model 535 dual trace oscilloscope and a Heathkit model V-7a vacuum tube voltmeter were used in the adjustment and calibration of the time delay analyzer. A laboratory square wave generator was used to simulate the Van de Graaff beam current pulse to provide triggering of the apparatus during most of the testing.

In order to determine the channel width, the frequency of the pulsed LC oscillator was compared, by display on the oscilloscope, with an external continuously running oscillator whose frequency could be accurately measured with a crystal controlled Beckman model 7351BR Eput meter. A conservative estimate of the accuracy of this method of channel width determination is plus or minus one per cent. This figure could be improved somewhat by utilizing a more direct method of comparing the separation of the delayed timing markers (which actually determine channel width) with the output of a crystal controlled oscilloscope calibrator, but unfortunately, such a piece of equipment is not available at the present time.

Uniformity of the channel widths was further checked by feeding randomly distributed pulses from a Cesium-137 source to the input of the analyzer. The number of counts recorded in the individual channels should be equal to within statistical deviations for perfectly uniform channel widths. Channel number one was found to be seven per cent wider than the average, due to transient effects in the first

cycle of the pulsed oscillator output, while the rest of the channels were found to be linear, or of equal width. This result agreed with the measurements made with the oscilloscope.

Stability of the analyzer was found to be adequate; no measurable drift in channel width was noted over a period of five days of operation with the same channel width. The channel width was measured as previously described at the beginning and end of each day's run, and at least once during the course of the day.

The analyzer was utilized, with channel widths of 9.56 microseconds, 15.60 microseconds, and 25.47 microseconds, to determine the time behavior of the leakage neutrons from a small geometry light water moderator. Results of these measurements are given by Epling (1960), as well as comparison with data obtained by other investigators.

CONCLUSIONS

The use of cascaded magnetron beam switching tubes as gate generators for a multichannel time delay analyzer has been shown to result in simple, dependable circuitry. Conventional analyzers utilizing ring circuits as gate generators require a considerably larger number of circuit elements in order to obtain twenty-six channels, and the resultant lack of reliability constitutes a serious drawback. The analyzer described herein comprises a valuable research tool which is particularly well adapted for use with the pulsed Van de Graaff accelerator.

In the opinion of this writer, the greatest room for improvement in the design of this instrument lies in the switching grid driving circuits and delayed timing marker generator. Investigation of possible simplification of these circuits is recommended.

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